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TITLE OF THE INVENTION

Lightweight Structural Component Made Of Metallic Ply Materials

PRIORITY CLAIM

This application is based on and claims the priority under 35 U.S.C. §119 of German Patent Application 102 38 460.6, filed on August 22, 2002, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to lightweight components made of metallic ply materials such as thin sheet metals. At least one metal ply covering the entire area of the component is secured to a further sheet metal ply by adhesive bonding. The invention also relates to a method for producing such lightweight structural components.

BACKGROUND INFORMATION

Conventionally known lightweight structural components comprise an outer skin which is reinforced on an inwardly facing side by

a stiffening or stiffening members. For example, conventional aircraft fuselages are constructed in such a way that the outer skin is reinforced or stiffened with the aid of ribs and stringers including so-called "clip". The stiffening members are secured to the inside of the outer skin by rivets, by adhesive bonding, or by welding. In order to adapt the skin thickness to localized load requirements, the skin thickness is reduced in areas where lower loads are effective to thereby reduce the weight of the skin particularly between the stiffening members. Thinning of the skin is performed by mechanical or chemical milling operations. These operations are known as "pocketing".

European Patent Publication EP 0,649,373 B1 corresponding to U. S. Patent 5,429,326 discloses a compound plate comprising at least a first and a second metal ply which are connected to each other by an adhesive layer. Such metal polymer laminates are particularly suitable for use as lightweight structural components in the aircraft construction because these laminates combine advantageous mechanical characteristics with a low structural weight. Due to the limited width of the sheet metals or metal foils to be connected with each other it is necessary to employ a splicing operation for the production of skin sections or fields for an aircraft fuselage. This reference describes the splicing operation. A local adaptation of the laminate thickness of the structural component to different load requirements in different locations is not addressed in this reference.

International Publication WO 98/53989 A1 describes a further lightweight structural component with adhesively bonded metal layers or plies. Compared to the disclosure of U. S. Patent 5,429,326 the International Publication discloses an improvement of the known splicing concept for bonding individual laminated composite panels to a structural component. Again, no local adaptation of the laminate thickness to different load requirements in different locations within the panel area are disclosed.

OBJECTS OF THE INVENTION

In view of the foregoing it is the aim of the invention to achieve the following objects singly or in combination:

to provide a lightweight laminated structural component that has different weight characteristics in different localized areas in accordance with load requirements that must be met by these localized areas;

to vary the thickness of such laminate materials so that these materials have a thickness that is larger in high load areas than in lower load areas while simultaneously avoiding any kind of milling operations;

to improve the tolerance characteristics of such laminated materials against damages, by limiting the progression

of cracks and maintaining a certain minimal material strength after damage has occurred; and

to provide a method for producing such laminate structural components having different strength characteristics in different locations of the laminate material without the need for any pocketing operations.

SUMMARY OF THE INVENTION

According to the invention there is provided a lightweight structural component made of thin metal plies including at least one first metal ply that is uninterrupted throughout its area and at least one second metal ply that is constructed as a framework forming a lattice or lattice structure and an adhesive bond between the first sheet metal ply and the second lattice sheet metal ply.

The use of at least one lattice sheet metal ply bonded to at least one uninterrupted sheet metal ply has the advantage that the lattice structure stiffens the structural component exactly where needed. The stiffening is capable of taking up a portion of the load. The load distribution can be controlled by the configuration of the lattice structure, thereby taking up some of the load that is conventionally taken up by the frame structure of an aircraft. A localized skin reduction by a pocketing between the stiffening members of the fuselage frame is no longer necessary because the respective weight reduction

is inherent in the use of a lattice structure as part of the laminated structure. The lattice structure provides a skin thickness reduction throughout the entire area of the particular skin section between the lands and struts of the lattice structure. Moreover, the construction of the lattice structure is easily adapted to the load requirements throughout the aircraft body skin. Another advantage of the invention is seen in that, compared to conventional stiffening features, there are no restrictions regarding the geometry and configuration of the lattice structure. Thus, the stiffening can be achieved in any desired direction lengthwise or circumferentially of the aircraft body frame and at any desired location of the entire fuselage, thereby tailoring the aircraft skin characteristics to the localized load requirements of the aircraft fuselage. The lattice work permits a differential bonding between the lattice and the uninterrupted ply or plies of the laminated structural component, whereby a crack stop effect is achieved. For example, a crack in the uninterrupted ply will be stopped if it spreads perpendicularly to the lattice ply when the crack enters the area where the lattice ply is bonded to the uninterrupted ply. The lattice ply, so to speak, impedes the progression or spreading of cracks, thereby stopping such cracks from growing.

According to the invention there is further provided a production method for making the present lightweight structural components. The present method comprises the following steps: preparing an uninterrupted sheet metal ply, preparing a lattice sheet metal ply, and adhesively bonding the two plies to each other.

Preferably, the adhesive bonding material is applied to the lattice and then the lattice is pressed against the uninterrupted sheet metal ply.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be clearly understood, it will now be described in detail in connection with example embodiments thereof, with reference to the accompanying drawings, wherein:

Fig. 1 shows a perspective view of a lightweight laminated structural component such as an aircraft body skin panel according to the invention;

Fig. 1A is an enlarged view in the direction of the arrow IA in Fig. 1;

Fig. 2 is a plan view of a lattice structure comprising a single lattice ply according to the invention;

Fig. 3 is a view similar to that of Fig. 2, however showing two lattice plies superimposed on each other and to form a lattice structure attached to at least one sheet metal ply;

Fig. 3A is a view in the direction of an arrow IIIA in Fig. 3 after reinforcing or stiffening ribs have been attached to the lattice structure;

Fig. 3B is a view in the direction of an arrow IIIB in Fig. 3 after attachment of reinforcing or stiffening stringers;

Fig. 4 shows an exploded view of the lamination structure of Fig. 3 prior to the attachment of reinforcing ribs and stringers; and

Fig. 5 is an exploded view similar to that of Fig. 4, however showing only one uninterrupted metal ply and two lattice plies.

DETAILED DESCRIPTION OF A PREFERRED EXAMPLE EMBODIMENT AND OF THE BEST MODE OF THE INVENTION

Fig. 1 shows a perspective view of a laminated lightweight structural panel 1 that comprises a lattice ply structure 4 and an uninterrupted ply structure 4A of sheet metal bonded together by an adhesive bonding layer 4B. The panel 1 is suitable for use as a skin section for an aircraft structural component such as a fuselage section. The design process of aircraft structural components requires that a multitude of different design criteria must be taken into account such as deformability, dimensional stability, static material strength, general stability, proneness to crack formations, crack progression, remaining material strength after the formation of cracks, corrosion resistance, and so forth. Further, it is very important the structural component

satisfies optimal weight reduction criteria. It has been found that metal laminates which have improved mechanical characteristics as compared to plane sheet metals while being simultaneously lighter, are advantageously useable as skin components of an aircraft fuselage.

Referring to Fig. 1A the sectional view illustrates that in this particular embodiment the lattice structure 4 comprises two lattice plies 5 and 6 bonded to each other by an adhesive bonding layer 4C and that the metal ply structure 4A comprises two, uninterrupted sheet metal plies 2 and 3 bonded to each other by an adhesive layer or ply 4D. The metal ply structure 4A and the lattice structure 4 are in turn bonded to each other by the adhesive bonding layer 4B.

The thin uninterrupted metal plies 2 and 3 may be produced as thin sheet metals of the following metal materials such as aluminum alloys, titanium alloys, steel alloys, copper alloys, zinc alloys, and magnesium alloys. The uninterrupted metal plies 2 and 3 each have a thickness of less than 2 mm, preferably a thickness within the range of 0.5 mm to 1.5 mm. However, if only one uninterrupted sheet metal ply 2' is used the thickness of that single uninterrupted sheet may be up to 5.0 mm.

The lamination structure makes it possible to select that metal alloy which is most suitable for the outer skin of an aircraft fuselage, depending on the individual or local load requirements set by an aircraft purchaser. For example, a corrosion resistant

metal layer may form the outer skin ply of the laminated structure while simultaneously using in the core of the structure primarily lattice ply materials that make the core especially light and stiff while simultaneously having the required material strength and tolerance against damages. The lattice ply or plies form the pocketing, thus avoiding conventional milling operations. Alloys having these characteristics are well known. Further, the respective individual ply thicknesses may be selected in accordance with the individual requirements so that an optimal tailoring of the skin characteristics of an aircraft fuselage becomes possible.

In the example embodiment of Figs. 1 and 1A the present laminated structural component or panel 1 comprises in addition to the uninterrupted first and second metal plies 2 and 3 at least one lattice ply 5, preferably two lattice plies 5 and 6 as will be described in more detail below. The lattice structure 4 formed by the two lattice plies 5 and 6 is bonded to the inner metal ply 3 by an adhesive bonding layer 4B. The lattice plies 5 and 6 each have a thickness as outlined above. The just described laminated panel 1 is stiffened when it is applied to the stringers and ribs of an aircraft fuselage as will be described below with reference to Fig. 3.

Fig. 2 shows, for example, the lattice ply 5 formed of horizontal lattice elements H and vertical lattice elements V. The horizontal and vertical lattice elements H and V enclose open fields or pockets 7, 8 and 9. In the finished lamination of the

panel 1 the fields 7, 8 and 9 form the reduced thickness pockets, whereby any mechanical milling or chemical milling is avoided according to the invention. Reinforcing struts 10, 11 and 12 are positioned individually where reinforcement or stiffening is desired. For example, struts 10 run diagonally from corner to corner in the fields or pockets 7 while reinforcing struts 11 run in parallel to the horizontal elements H in the fields 9. Reinforcing struts 12 run in parallel to the vertical lattice elements V in the fields 8.

Figs. 3, 3A and 3B show a laminated lightweight fuselage component 15 for an aircraft body according to the invention. A body skin 16 is formed preferably by two lightweight sheet metal plies including the first ply 2 and the second ply 3 bonded to each other at 4D. The lattice structure 4 comprising two sheet metal lattice plies 5 and 6, for example, is formed by adhesively bonding the two lattice plies 5 and 6 to each other. For this purpose, the strip shaped lands of the lattice ply 6 must at least partly coincide or register with the lands of the lattice ply 5. Stiffening members 19 in the form of ribs are adhesively bonded to vertical lands V. Further stiffening members in the form of stringers 18 are secured to horizontal lands H. However, the stiffening elements 18 and 19 may also be secured by riveting or welding rather than by adhesive bonding. The lattice structure 4 is at least partly present under the stiffening elements 18 and 19. However, additional lands or stiffening members may be provided in the open skin fields 17 such as are shown at 11 extending in parallel to the horizontal

lands H and as shown at 12 extending in parallel to the vertical lands V. The sheet metal ply 5 comprises for this purpose a lattice structure that is positioned under the stiffening elements 18 and 19 in the form of stringers and ribs. Directly above the ply 5 with its framework struts 11 and 12 there is arranged the sheet metal ply 6. The ply 6 is directly connected to, or rather the lands of the ply 6 are directly positioned under, the stringers 18 and ribs 19. The thus formed lattice 4 takes up a portion of the load that conventionally was taken up by the stringers 18 and ribs 19 of the conventional aircraft frame structure. Thus, the stiffening elements 18 and 19 can now be made smaller, whereby an additional weight reduction has been achieved.

The lattice 4 is connected with the metal plies 2 and 3 by an adhesive bonding. Conventional metal adhesives, such as reaction adhesives, are used for the present purposes. Such adhesives are cured by a chemical reaction. Epoxy films manufactured by CYTEC Engineering Materials, Inc. under the Tradename FM94 is suitable for the present purposes. Compared to fiber reinforced ply composite material it is a substantial advantage of the invention that the relative expensive fiber layers are no longer required. The adhesive bonding as employed according to the invention does not result in an integral connection between the several plies of sheet metal. However, the invention achieves a crack stop effect, particularly where a crack extends substantially perpendicular to one of the lands of the lattice or perpendicularly to the a lattice strut 10, 11 or 12. In such a

case the adhesive bonding ply directly prevents a crack progression in the lattice strut which bridges the crack and thereby either impedes the expansion or directly stops a crack.

Furthermore, an efficient manufacturing is achieved with reduced costs, particularly when the lightweight structural component or panel 1 is produced in a single continuous manufacturing operation, whereby the individual uninterrupted sheet metal ply or plies and the lattice structures with the stringers 18 and ribs 19 are adhesively bonded simultaneously. This efficient and less expensive manufacturing can also be achieved by either securing the stringers and ribs to the lattice structure prior to bonding the lattice structure to the uninterrupted ply or plies or the stringers and ribs 18 and 19 can be secured to the skin structure 16 after the lattice has been bonded to the uninterrupted ply or plies to form the skin structure 16. In both instances the bonding of the plies to each other and the securing of the ribs 19 and the stringers 18 to the lands of the lattice can take place simultaneously. Further, it is possible to connect the stringers 18 to the lattice as described above by adhesive bonding and then to connect the ribs 19 in a following step, for example by conventional methods such as riveting or welding. Similarly, the ribs may be adhesively bonded first to the lattice while the stringers are then riveted to the skin structure 16.

Fig. 4 shows a perspective view of the ply structure of the lightweight structural component or panel 1 shown in Fig. 3. The lattice structure 4 comprises the sheet metal plies 5 and 6 with

their strip shaped lands and struts 10, 11, 12 at least on one of the plies 5 or 6. The uninterrupted plies 2 and 3 are bonded to each other and to the lattice 4. By selecting the ply thickness within the range of 0.5 mm to 2.0 mm, by configuring the lattice 4 particularly the position of the strip shaped lands and struts, and by selecting the appropriate metal or metal alloys for the plies 2, 3, 5, 6 it is now possible according to the invention to tailor the lightweight structural component to have optimal characteristics relative to the requirements that must be met by an aircraft fuselage structure 15. The lattice plies 5 and 6 may be both constructed with struts 10, 11, 12 or only one lattice ply 5 or 6 may have such struts. In Fig. 4 the inner lattice ply 5 is provided with struts 10 and 11, for example.

The structural component 1' made in accordance with Fig. 5 is similar to that of Fig. 4 but has only one uninterrupted sheet metal ply 2'. In this embodiment the thickness of the single uninterrupted sheet metal ply 2' may be thicker than outlined above, for example up to 5.0 mm depending on the load requirements that must be met by the laminated structure that forms the structural component 1'.

Although the invention has been described with reference to specific example embodiments, it will be appreciated that it is intended to cover all modifications and equivalents within the scope of the appended claims. It should also be understood that the present disclosure includes all possible combinations of any individual features recited in any of the appended claims.